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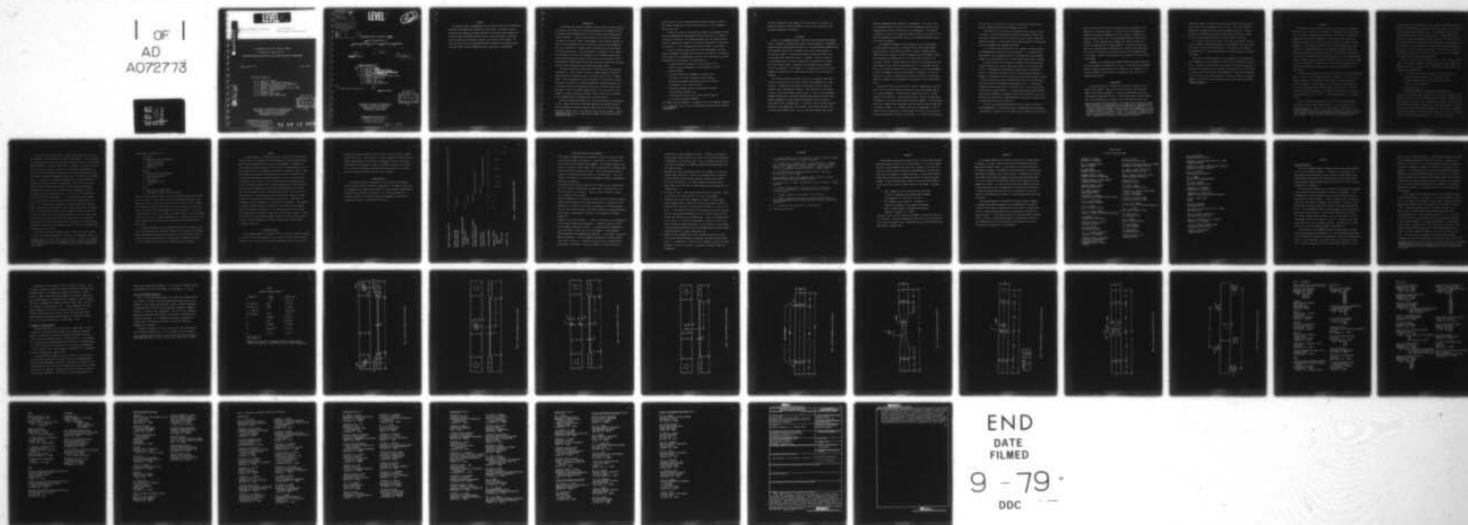
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RECOMMENDED PLAN FOR PROJECT FRACT: A CRITICAL EVALUATION OF FR--ETC(U)
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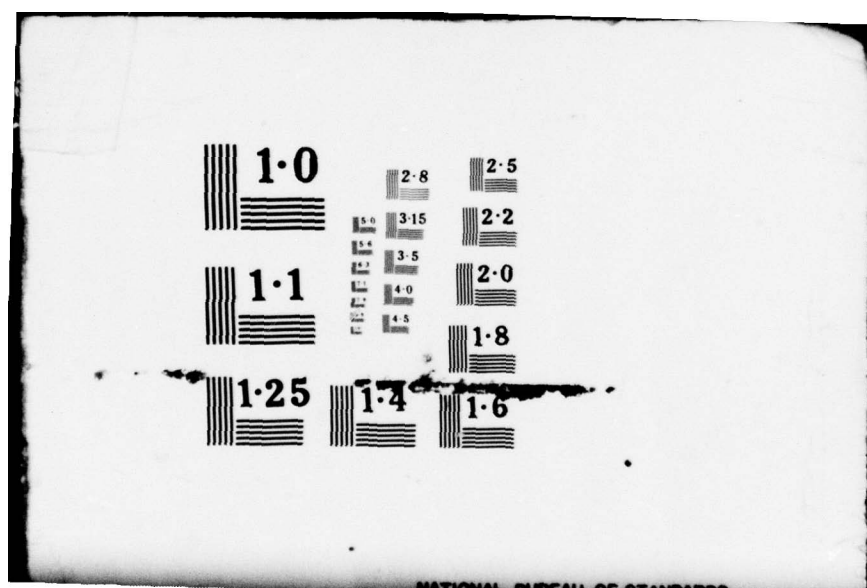
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Carnegie-Mellon University
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DEPARTMENT OF
MECHANICAL ENGINEERING

Recommended Plan for Project FRACT
A Critical Evaluation of
FRACTURE RELATED ANALYTICAL AND COMPUTATIONAL TECHNIQUES

Report SM 79-3A

July 1979

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6 Recommended Plan for Project FRACT:

A Critical Evaluation of
FRACTURE RELATED ANALYTICAL AND COMPUTATIONAL TECHNIQUES

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PREFACE

This report outlines a recommended plan for critical evaluation of Fracture Related Analytical and Computational Techniques, Project FRACT. The report includes suggestions and commentary from many members of the Advisory Group (Appendix B), who were given a preliminary draft for review. Wherever feasible, we provide both the initial text and these responses in this version of the report. We note also that most of the responses were quite supportive of the broad concept of Project FRACT, and that suggestions were aimed toward its improvement.

INTRODUCTION

It has been well over half a century since the first elastic analyses [1] of stress in the vicinity of a crack were performed, but somewhat less than two decades since meaningful results [2] for elastic-plastic problems have become available. Since the late 1960s the latter type of calculation has grown to be routine in many establishments. Unlike elastic analyses for which careful evaluations and cross-checks have long since been completed - see, e.g., Peterson [3] - elastic-plastic procedures have not been subject to a wide-scale scrutiny. Thus, while there is a growing number of sources for such analysis, there is no standard or set of standards whereby these results may be evaluated in terms of their accuracy and resolution. This is troubling both intellectually and in terms of specific applications involving fracture related configurations and which demand good answers.

The case of particular interest here is one involving fracture-related configurations. These include a variety of cracked laboratory testpieces, sharply notched test specimens used in screening tests [4], and - of great import - their counterparts in service structures. The reason for concern, of course, is that there is increasing demand for structural integrity and, at the same time that the technology for dealing with elastic-plastic fracture grows, so must the primary mechanics base. It is of little use, for example, to define a fracture criterion if there is doubt as to the quality of the (computationally) predicted stress and strain fields.^{1*}

None of this should be inferred as a criticism of analysts or developers of code. Indeed, such workers have made important contributions that now and in the future will stand as being of great value in our overall effort to unravel, however slowly, the problem of elastic-plastic fracture. Rather

^{1*}Superscripts refer to notes taken from the comments of the Advisory Group, beginning on page 15.

the difficulty lies in not having pulled together the essence of each of these many contributions so that the great power that is their potential may be wisely used.

A window on the need for such effort was given by the comparative study done under ASTM auspices and reported by Wilson and Osias [5]. Using the "round robin" format for a well-defined problem, the study showed that ten solutions compared very favorably in the elastic range but, at a high level of excitation, "...the difference[s] between solutions is [are] major."

It must be true that great minds run in the same channel, for other groups have begun to contemplate some action on this problem*. We describe here an effort lasting approximately two years, and involving ten to twelve investigators as participants. The objectives are

- to replicate physical behavior of elastic-plastic flow in fracture related configurations, using computational and/or analytical means;
- to provide the technical community a firm basis for such analyses, by broad dissemination of the results;
- to establish benchmark problems and solutions for future investigators to check their own work;
- to establish thereby a basis for evaluating the quality of any pertinent analysis; and
- to move the state of the art of elastic-plastic analysis to a position of greater certainty.

This effort thus has high aims; it responds to what by an apparent consensus is a considerable need. How we have proceeded to plan for Project FRACT is

*See Appendix A.

outlined in Appendix B; what appears in the main report is an overall procedure, an outline of specific problems to solve, and an indication of the anticipated phasing of the Project.

PROCEDURE

FRACT is a recommended program of activities whose potential participants "solve" a sequence of problems using quite different approaches: experimental, computational and, where appropriate, analytical. Each problem in the sequence is carefully defined, and each one is intended to test one or another aspect of the solution method(s). Of particular concern is modeling, whether it be of load application, material behavior, or geometry. Thus the solutions to each problem are to be closely compared and, as differences are identified, their sources found. Ultimately, these solutions must be brought closely into register. In this manner, it is expected that the art we term modeling is enhanced and at the same time the quality of the solutions is improved.

The specific problems are chosen to fall into a sequence, from those involving a uniform stress or strain field to those engendered by a crack or notch. A progression of problems is intentionally chosen so that the degree of stress concentration increases. The reasons for not dealing exclusively with crack problems are quite simple: A crack is such a dominant geometric feature that it may mask inadvertent modeling errors which, while perhaps unimportant in simple laboratory specimens, become essential in more complex service configurations. In addition, crack-tip stress analyses necessarily incur numerically large strains - which outrun the usual type of stress-strain material data - but it is not clear whether these strain

values are meaningful and/or capable of corroboration. As a result, some of the problems chosen for study will involve intermediate levels of stress concentration which may at first appear to be conservative. This feature is expected to pay off in the long run, however, especially as there is afforded an opportunity to evaluate critically the modeling techniques used by the various participants.

It is assumed for purposes of this discussion that the participants in Project FRACT would work on a contractual basis; should such funding become available, it may derive from either a single or combined sources. Whatever the mode, funding is needed to guarantee timely performance, reporting on schedule, and other aspects of each participant's work such that the overall Project is neither impeded nor thwarted by the exigencies any one participant may face within his/her organization. It is intended that support is for solving the problems within the sequence, and not for development of code or equipment, nor for extensive amounts of education, nor for incidentals (e.g., travel, reporting) beyond those used directly in the Project. Materials, computer time, and manpower are expected to be the primary direct costs.

Monitoring of the Project involves two aspects, administrative and technical, and it could well require the talents of two or more people working in a close partnership. The administrative monitoring will be in a form settled by the sponsor(s). The technical monitor(s) need not be employed by the sponsor(s), but may be drawn from the technical community. No such person can be both a monitor and a participant, and the monitor(s) must be qualified to perform as needed, i.e., credible; free to act; unencumbered by lack of funds or special relationships to participants; and closely in tune with the objectives and process involved in this Project. It is after all the monitor

who says that a set of results is "good," in some sense, and he/she must have the standing in the technical community to do so.²

A protocol for the Project may be established at this stage, at least in outline. Since the problems to be treated are sequential, there is an order both in which they are to be solved and in which results may become generally available. In some cases this may require deferral of publication, and all participants must recognize this need.

It is essential that each problem in the sequence be uniquely defined and comprehensively understood by each participant. It is believed that the problems as now conceived meet such a requirement but, should there be changes in the problem definition, all participants must be fully informed.

All participants would be expected to progress from simpler problems to more difficult ones, results being gauged closely by the technical monitor(s). Correspondence of experimental, computational, and analytical results is the signal for moving to the next, more difficult problem in a sequence. Discrepancies must be addressed; the participant should be allowed to repeat his/her work with the technical monitor's aid, the target being close replication on the computer of experimental data. In this manner, findings for each problem would be released jointly, with all participants contributing to any publication. It is expected that each such publication would include information in support of the Project's objectives, e.g., the modeling lore required for a benchmark problem, the quality of result, and a new definition of the state of the art.³

Criteria for selecting participants are easily stated but subtle in their implementation. Participants should be experimentalists and analysts (computational or otherwise) of the highest calibre, people who can be relied

upon to deliver the best solutions to each problem in the sequence, as delineated in a subsequent section. As a group, they should represent the range of techniques and approaches now in use so that, for example, the Project does not wind up with a half dozen people using the same code for analysis*. Apart from quality and breadth, the issue of criteria for selection of participants is largely empirical. A process outlined in the next section provides means for effecting such a result, and we anticipate that it will be followed as a part of the review of the preliminary draft of this report. Results of that process will be appended to the final form of the report.

In summary, this section defines Project FRACT and outlines the rationale chosen whereby its objectives are to be met. The structure is described briefly, together with an outline of the protocol for its operation. Criteria for selection of participants is touched upon, and is picked up in another context, below.

PARTICIPANTS

It would be altruistic to conceive Project FRACT in terms of a large number of participants. While such a scale of activity would have great impact on the technical community, it would also necessitate an excessive concentration of funds for this work. Hence a balance must be struck between what is desirable and what is realistic to do, and great care must be ex-

ercised in selecting the participants in the Project. Most certainly, we seek *While differences in the procedures various candidates for participation might use must be taken into account, there is no intent here to "qualify" or to "disqualify" any given procedure. There certainly are differences to be found from one procedure to the next; we believe these to be far less important than the manner in which the procedure is used. It is nonetheless sensible to test this as a working hypothesis, so to speak, by ensuring that alternative procedures, computational or otherwise, are included in the Project.

success and, thereby, we should focus on those candidates for participation who are most likely to contribute to that success. That usually implies people who have established their abilities through prior work. Typically one infers the need for some generally acknowledged reputation, but there may also be good candidates who are less widely known or recognized.

As a result, we rely on two points. The first, noted above, is the explicit statement of need for participants of the highest calibre who can be relied upon to deliver the best solutions to each problem in the sequence. The second point is a simple procedure which is believed to give the information needed.

This report has been reviewed by a large segment of the pertinent technical community*, and the commentary and reactions of these people were solicited. In addition, we have asked all such readers to nominate candidates for participation, bearing in mind the character and objectives of Project FRACT. As a result, several people have been suggested, and their names transmitted with this report to the sponsoring agency. However, anyone in the technical community is potentially a participant, should Project FRACT become funded.

*Refer to Appendix B.

PROBLEMS

The problem to be solved can be defined in one or both of two manners. One could, in the context of elasto-plastic or incremental theory, delineate a set of initial- and boundary-value problems. The physical or experimental counterparts would then be inferential. To the extent that satisfactory comparison between the two types of solution is the key to success, and that modeling is a clear target of the Project, this form of definition is inappropriate. The preferred approach is to describe the problems in physical terms, and to minimize or eliminate ambiguity. We follow that approach here. The central issue is modeling per se, and the specifics of load representation, material characterization, and geometric matters are left to the analyst, computational or otherwise.⁴ The analyst will of course be provided with precise detail of the experimental arrangement and certain key information, e.g., tensile data.

Certain general comments are in order with respect to all problems defined below. First, it is anticipated that 6061-0 aluminum will be used⁵ in all experiments and that all test specimens will be made from the same original pieces of material*. The specimens are to be annealed after machining so as to avoid localized regions of work-hardening which would lead to a spatial variation of material properties. For comment on this effect, see [6] and the ensuing discussion [7, pg. 891]. Abusive machining [8] is to be avoided as well.

Data to be extracted from each test will fall into three categories. First, there is overall structural response, e.g., load *vs* deflection at a well-defined position. While this may seem a rather crude measure, it is

*It will be useful to make an excess number of specimens, of course, and care must be taken to maintain any directionality which is determined to exist in the (preferably single) product form from which the specimens are cut.

typically used in fracture characterization and must therefore be accurate.⁶ Second, one may describe coarse interior data such as might be used to check for load alignment and specimen symmetry; such information should also be corroborated by analysis. Third, fine-scale data, as determined in the vicinity of a stress concentration, may be extracted. The specific data to be extracted from any one problem are of course peculiar to that problem. We note, however, that all problems or tests within Project FRACT should produce results of the first two types described. Fine-scale data should also be obtained and used in direct form so that there is no risk of compromise from the process of reducing experimental data.

Clearly, fine-scale data are available in two forms: strains, as from (small) strain gauges carefully placed and oriented, and displacements as determined by several techniques. Local displacements (either relative or absolute) can be measured via:

1. clip gauges placed across the faces of a notch or crack, at various distances from the root of the stress raiser;
2. silhouette photography of the profile of a specimen, as it changes with load progression;
3. moiré techniques; and
4. holographic methods, including speckle photography [9].

Note that strain gauges and clip gauges give point values of quantities they measure, silhouettes provide information along a boundary, and that the last two techniques yield field data. A hierarchy thus exists in the fine-scale data which may be obtained, in terms both of the effort needed to extract the data and the degree to which detailed comparisons can be made. The general approach for problems in Project FRACT is to make judicious use of these techniques, obtaining as much information as is economically feasible.

The load cycle for all problems is expected to range from nil to a level where general yield is under way, followed by load removal*. It is anticipated as a minimum that data in each of the three categories (above) will be obtained: when the specimen is wholly (or very nearly so) elastic, at two or three intermediate levels of excitation, at peak load, and following load removal. In addition, structural response and certain of the coarse interior data should be recorded continuously throughout the load cycle. For much of this information, it is necessary to record data automatically. The most desirable arrangement would allow continuous recording and storage of the test data on magnetic tape with software for retrieval and both analogue and digital presentation of the data. This software should be sufficiently flexible for plotting specific measurements (e.g., a given strain) as a function of either time or another measurement. It is recognized that a data system with these capabilities may be unobtainable and other approaches may be required. An acceptable approach might be to create automatically generated plots of all strain and displacement data as functions of applied load and/or time. If applied load is chosen as the independent variable, a plot of applied load *vs* time must be generated during testing. As a last resort, data scans at discrete time or load intervals during the test are a marginally acceptable means of obtaining response data. Regardless of the specific data acquisition system used, all response data must be stored in a form permitting subsequent retrieval and use.

The overall sequence of problems comprises three sets, four thin plate (or nearly plane stress) geometries, five round (or axisymmetric) shapes, and at least one thick (or nearly plane strain) specimen. The sense of a sequence

*In some instances at least, it is appropriate to go through a load reversal as well. Whether this is to be incorporated into analysis may be decided at a later stage.

obtains from the following list:⁷

1. Thin plate
 - a. smooth, no stress concentrator
 - b. circular perforation
 - c. symmetric U notches
 - d. center crack
2. Round
 - a. smooth, no stress concentrator
 - b. reduced cross-section
 - c. mild U notch
 - d. intermediate U notch
 - e. V notch
3. Thick
 - a. edge crack, four-point bend
 - (b. same geometry, other load configuration)

Obviously the two smooth specimens (1a and 2a) provide necessary tensile data. They also serve as a cross-check on both the loading mechanism used in the laboratory and the basics of any analysis. The hole radius (1b) is chosen to be in proportion to that of the mild U notch (2c), and the other two U notch cases (1c and 2d) are the same geometry (within a scale factor). The center cracked thin plate (1d) is not covered by an ASTM standard, as is the V notched round [4,10], but it is a familiar configuration in certain types of less formal fracture testing. The same is true of the four-point bend specimen in plane strain.

It should be apparent that the progression from tensile testing to fracture related specimens has been chosen carefully with an effort to facilitate both experimentation and modeling, and with an eye on opportunities for isolating any difficulty that may arise in pursuing the sequence of problems. Explicit description of the individual problems appears in Appendix C.

PHASING

As indicated above, a considerable amount of review of the planning for Project FRACT is anticipated, and other preparations (notably funding arrangements) must be made before the Project may be implemented. Assuming that those aspects have been completed, it is relatively straightforward to devise an ordering for the various phases of the Project. Reference to Table 1 shows that material acquisition and specimen fabrication proceed in parallel with establishing the necessary contractual relations so that, by the end of the sixth month, tensile data are to be in hand and the more substantive parts of the Project may proceed. Note that both experimentation and analysis have initial portions, during which test fixtures and procedures may be checked out, and any necessary start-up for analysis may be done. Reporting (of an interim nature) is called for during this period so that, where any changes are made to the original problem definitions owing, say, to laboratory requirements, there is opportunity to assimilate this information. The schedule or pacing of problem solution is implied by the subsequent interim reports, and final reporting is indicated. If this schedule proves to be too tight, some loosening may be achieved by deferring the final report slightly. Should the pacing be slow, additional problems - especially ones dealing with thick sections - may be contemplated. Note that technical monitoring proceeds throughout the Project.

CONCLUDING REMARKS

This planning document is intended to be terse so that no extensive summary is in order. The overall procedure is described so that the scope and the approach are clear. We touch the issues of participants and how they are to be

selected, the actual problems in their sequence - much the technical centerpiece of the Project - are outlined in a manner designed to bring out the conceptual underpinnings of the Project, and phasing is outlined. We believe that pursuit of this effort will meet the objectives stated in the Introduction, and that its successful conclusion will advance the art to a degree and for its many practitioners that will prove valuable.⁸

ACKNOWLEDGMENTS

This planning effort was sponsored by the Office of Naval Research, and this initial vote of confidence is appreciated. The members of the Planning Committee also express their gratitude to their respective organizations for making time available to participate. The Planning Committee is, in addition, in debt to the Advisory Group whose commentary and thoughtful contributions helped to consolidate this activity.

MONTHS FROM PROJECT START-UP	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
MATERIAL ACQUISITION	—																								
SPECIMEN FABRICATION					—																				
ESTABLISHING CONTRACTUAL RELATIONS:																									
EXPERIMENTALISTS																									
ANALYSTS																									
INITIAL TESTING (E.G., TENSILE)																									
CONTINUED EXPERIMENTATION																									
INITIAL ANALYSES																									
CONTINUED ANALYSES																									
TECHNICAL MONITORING																									
REPORTING, INTERIM																									
THIN PLATE																									
ROUND																									
THICK SECTION																									
REPORTING, FINAL																									

TABLE 1. ESTIMATED PHASING FOR PROJECT FRACT

NOTES FROM ADVISORY GROUP RESPONSE

1. "The reason for undertaking such an exercise...needs to be stated in terms of the cost and safety of structures." Concern here is that the basis of Project FRACT is more academic than pragmatic. The seemingly academic character of the Project derives largely from its progression from (geometrically) simple to difficult problems, to be sure. This does not detract from its objective of obtaining accurate results, on a reliable basis. This is essential if the analyst is to be able to accommodate arbitrary configurations, materials, and loadings.
2. The organizational structure, especially with respect to the technical monitor not also being a participant, has been noted. The intent here is to avoid any potential for conflict. Certainly, were all parties to agree, this constraint could be lifted.
3. There are suggestions to the effect that Project FRACT be merged with similar efforts being developed within professional societies, in particular, ASTM Committee E-24. Were this to be done, the opportunity for funding (page 4) could be lost in that the usual "round-robin" procedure provides participants with anonymity, whereas public reporting is a requirement for federally funded work.
4. Comments on this point included: "...there is relatively little [discussion] on the range of computational procedures..." especially special or singularity elements, that might be used; "...the same analytical formulation of the stress-strain curve be used by all participants..." the preference being expressed for the Ramberg-Osgood equation; "...that several...plasticity models be employed..." with four suggested specifically; and that insufficient credit is given to "...methods of analysis based on closed form approximations." We believe it would run counter to the entire spirit of

the Project to control modeling too closely. Certainly, the selection of participants would proceed so that there is no significant duplication of methodology - see footnote, page 6 - but to do more could easily bias the Project with respect to identifying modeling problems precisely and then resolving them.

5. This material choice has been criticized. The 0 temper is too soft and exhibits some strain rate sensitivity, and aluminum does not replicate behavior found in ferrous alloys, especially pressure vessel steels. The selection of material will require further investigation and, as some comments have indicated, specimen preparation must proceed with considerable care.
6. Care must be taken to check for specimen distortion at the grips. Coarse interior data will compensate where this could be problematic.
7. Additional specimens have been suggested, including: center-loaded, simply supported beam; a pressurized, thick-walled pressure vessel; an uncracked beam to precede 3a; and additional thickness (0.2 and 0.25 in) for 1d. It has been noted that the round specimens are possibly too small, and that thick specimen performance will vary from the interior to the surface where observations are performed. Finally, the thread relief on 2a (Figure 5) is noted to be non-standard. Certainly it will be in order to refine the specimen design but, at this stage, it is not evident that additional specimen types can be assimilated into the Project without creating difficulty in terms of additional cost.
8. Support for the conceptual basis and the technical objectives of this Project were evident throughout the responses received from the Advisory Group. It is reasonable to infer that the respondents saw that the Project addresses a real need, and that it is planned in a manner to meet that requirement.

REFERENCES

1. C. E. Inglis, *Transactions of the Institution of Naval Architects* (London), 60 (1913) 219-230. See also the ensuing discussion.
2. J. H. Argyris and D. W. Scharpf, *ZAMP*, 23 (1972) 517-552; P. V. Marcal and I. P. King, *International Journal of Mechanical Sciences*, 9 (1967) 143-155; J. L. Swedlow, M. L. Williams, and W. H. Yang, *Proceedings of the First International Conference on Fracture*, 1 (1965) 259-282.
3. R. E. Peterson, *Stress Concentration Factors*, 2nd ed., John Wiley, New York (1974), 1st ed. (1953).
4. *Rapid Inexpensive Tests for Determining Fracture Toughness*, National Materials Advisory Board Report NMAB-328 (1976).
5. W. K. Wilson and J. R. Osias, *International Journal of Fracture*, 14 (1978) R95-R108.
6. J. L. Swedlow, *International Journal of Fracture*, 5 (1969) 25-31; See also J. H. Underwood et al., *Engineering Fracture Mechanics*, 2 (1971) 183-196.
7. J. L. Swedlow, *Computers and Structures*, 3 (1973) 879-898.
8. W. A. Thomas, Recognition and Control of Abusive Machining Effects on Helicopter Components, American Helicopter Society National Forum (1973), preprint 750.
9. K. A. Stetson, *Optical Engineering*, 14 (1975) 482-489.
10. ASTM Standard E602-76T.

APPENDIX A

Other groups contemplating an effort similar to Project FRACT have been identified during the course of its planning phase. It so far would appear that two or three proprietary activities are in progress. They tend to be specific to one application or another, and information as to status and results have yet to appear in the open literature. At least three voluntary efforts under the aegis of one professional society or another are being planned. To date they appear more limited in scope than Project FRACT but that is not to say that more extensive plans will not emerge. The groups are

1. ASTM: Committee E-24 on Fracture Testing, Task Group E-24.08.02 on Computational Techniques and Procedures. Co-chairmen are D. M. Parks and W. K. Wilson.
2. EGF (European Group on Fracture): Chairman is J. D. Harrison, and funding is being sought from Euratom.
3. SESA: Fracture Committee, Subcommittee on Numerical Modeling. Chairman is F. W. Smith.

There may also be a similar interest within ASME, but definite word has yet to be received. The point is nonetheless clear that the issues raised here are of general interest so that a significant fraction of the technical community seeks to address them.

APPENDIX B

It was deemed important from the very outset that this planning effort not proceed in a vacuum. Apart from the chance of duplicating work that might begin elsewhere, there is a clear need to tap as broad a resource as was feasible to develop. Accordingly, an Advisory Group was identified, and people have now agreed to serve in that capacity. As planning went forward, these people were notified of progress in outline rather than detail form. It is to this Group that the preliminary draft of this report was sent for comment and critique. It is also from this Group that nominations for participation were solicited. The membership of the Advisory Group follows; it is clear that overlap with other activities is established so that, were there to be some duplication of effort, it could be made useful rather than inadvertant.

The Planning Committee was drawn from the larger technical community to represent the expertise needed for the planning phase of the Project. It has met three times (13 September and 31 October 1978, 17 January 1979) as well as having developed much of the written material upon which this report is based. Dr. Alan Kushner served on the Planning Committee through the end of 1978, as the ONR representative; his professional association then changed and he did not participate in the completion of this work. The Committee is grateful for his contribution.

Project FRACT

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APPENDIX C

Thin Plate Problems

This set of problems shares the common structural basis shown schematically as a test specimen in Figure 1. It consists of a rectangular thin plate gauge section, subjected to remote, in-plane, uniaxial tension introduced through thickened end tabs. These end tabs are to be integral parts of the specimen; separately fabricated pieces attached to a plate of uniform thickness are not acceptable.

The four distinct problem types of interest are differentiated according to the structural stress concentration contained in the specimen. Type 1a specimens have no such concentration and are thus unnotched tensile specimens of the type shown in Figure 1. Type 1b specimens contain a single circular hole at the center of the gauge section (Figure 2), and Type 1c specimens contain two opposed edge notches transverse to the applied loading (Figure 3). Type 1d specimens contain a fatigue-sharpened crack placed normal to the applied loading (Figure 4). The principal dimensions of all notches are the same, regardless of notch type. Thus, the hole diameter D in Type 1b specimens, the total notch depth $2l$ in Type 1c specimens, and the total crack length $2a$ in type 1d specimens are equal. The principal notch dimension (D , $2l$, $2a$) for any notched specimen is indicated by λ .

The thickness B of the gauge section must be small enough to warrant plane stress modeling of specimen behavior, so that experimental measurements on the surface of the specimen can be meaningfully compared with computational results. At the same time, it is necessary that B be significantly larger (e.g., an order of magnitude) than the microstructural dimensions, such as

grain size, of the specimen material. A satisfactory gauge section thickness is thus somewhat dependent on the material of interest. A gauge section thickness of 0.10 inch, which is at least marginally adequate for materials as coarse as ASTM grain size number 1, is chosen for the purposes of this discussion. It is assumed that this choice is justified by microstructural examination of the actual specimen material prior to testing. If such examination indicates that alteration of the proposed gauge section thickness is warranted with regard to microstructural considerations, the consequences of such a change on specimen fabricability and susceptibility to handling damage must be assessed. All specimen types must have the same gauge section thickness.

All other gauge section dimensions are directly or indirectly related to gauge section thickness. See Table 1. In the notched specimens (Types 1b, 1c), the principal notch dimension λ must equal or exceed ten times the gauge section thickness, while the gauge section width W must be from 2.5λ to 5.0λ . Other notch dimensions are as indicated in Figures 3 and 4. Unnotched Type 1a specimens must have the same gauge section width as notched specimen types. Lower bounds on λ and W (i.e., $\lambda=1.0$ inch, $W=2.5$ inch) are chosen for this discussion to avoid any unnecessary requirements on testing machine capacity. The gauge section length L is chosen equal to five times the specimen width. It is assumed that this length is large enough to provide an axial separation of $0.5W$ or more between the local stress and strain perturbations induced at the end tabs and the notch (if any). The validity of this assumption must be continuously addressed throughout the course of the experimental and analytical phases of this work; instrumentation and data acquisition are to be designed to meet this requirement*.

*Internal Planning Committee correspondence provides further detail on these points; the overall objectives are described on pp. 8-10 of the main part of this report.

Configuration of the loading end tabs is indicated in Figure 1. End tab width is chosen to be identical to gauge section width to simplify specimen fabrication and to eliminate any potential difficulties in a width transition region. Other loading tab dimensions are chosen to assure adequate loading capability for unnotched Type I specimens. End tabs sized on this basis are adequate for loading of notched specimen types. Total end tab length L_T is chosen equal to $1.5W$. A single loading pin hole with a nominal diameter D_T of 1.0 inch is located as shown in each end tab. In actuality, these holes must be slightly larger than indicated to avoid binding between the specimen and the loading pins. Based on this loading pin size, the end tab thickness B_T is chosen equal to $7.5B$.

Axisymmetric (Round) Problems

This set of problems is also predicated on a common shape. In order to fabricate the specimens from a product form of reasonable thickness, however, the dimensions are scaled down somewhat from those of the Thin Plate series, and we assume the basic structural shape of a 1-inch diameter rod. The end fittings are depicted here as standard, to fit threaded grips. If it should develop that an alternative is both available and preferable it will of course be used. Apart from that, configuration of the specimens follows the considerations outlined above.

The smooth (Type 2a) specimen is shown in Figure 5; it should serve a source for tensile data as well as being a check on the loading systems, given proper instrumentation. The Type 2b specimen allows extensive local straining without risk of failure at the grips, and it will serve as a significant check on computation. Specimens 2c and 2d are related to 1b and 1c, as noted above; specimen 2e is as close to a cracked configuration as is

feasible while preserving axisymmetry. It also relates to fracture testing, as discussed in the text of this report [4] (see Figures 6, 7, and 8)*.

Thick (Plane Strain) Problems(s)

This is a four-point bend specimen with an edge crack halfway through the thickness. Thickness should be as great as the product form allows, probably 1.5 inch, and the cross-section is square. Loading is generated by opposing pairs of rollers, half the specimen's thickness in diameter, spaced at 6 inch and 12 inch, respectively. Thus no roller is immediately opposite the crack front, and loading is introduced at a distance of four times the crack depth. (It is assumed that the crack is generated by a fatigue process, following usual practice, and that the specimen is annealed after fabrication.)

Depending on progress of the work, we may wish to use the same specimen in three-point bend as well. This is a variant of the standard K_{Ic} test in that the span/width ratio is eight rather than four (see Figure 9).

*The notch angle shown in Figure 8 may be reduced from 90 deg to 60 deg.

TABLE 1
Nominal Specimen Dimensions

Dimension ¹	Bounds	Assumed Value
B	— ²	0.10 inch
$\lambda = D$ (type 1b)	$\lambda \geq 10B$	0.25 inch
$\lambda = 2l$ (type 1c)	$\lambda \geq 10B$	1.5 inch
r (type 1c)	--	0.3125 inch
$\lambda = 2a$ (type 1d)	$\lambda \geq 10B$	1.0 inch
W	$2.5\lambda \leq W \leq 5$	2.50 inch
L	$L \geq 5W$	12.50 inch
B_T	$D_T B_T \geq 3WB$	0.75 inch
D_T	$D_T B_T \geq 5(W - \lambda)B$	1.00 inch
L_T	$L_1 \geq 1.5W$	3.75 inch

¹See Figures 1-4.

²Gauge section thickness is bounded from below by microstructural dimensions of material, and from above by plane stress considerations.

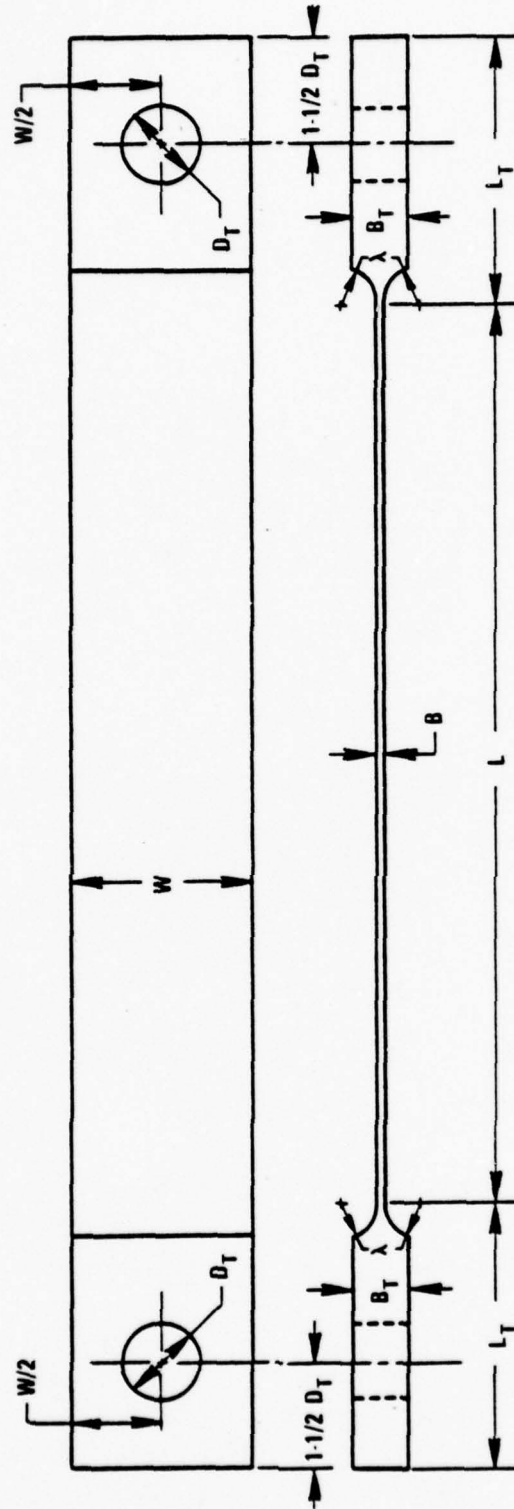


Figure 1. Schematic Configuration of Type 1a Specimen

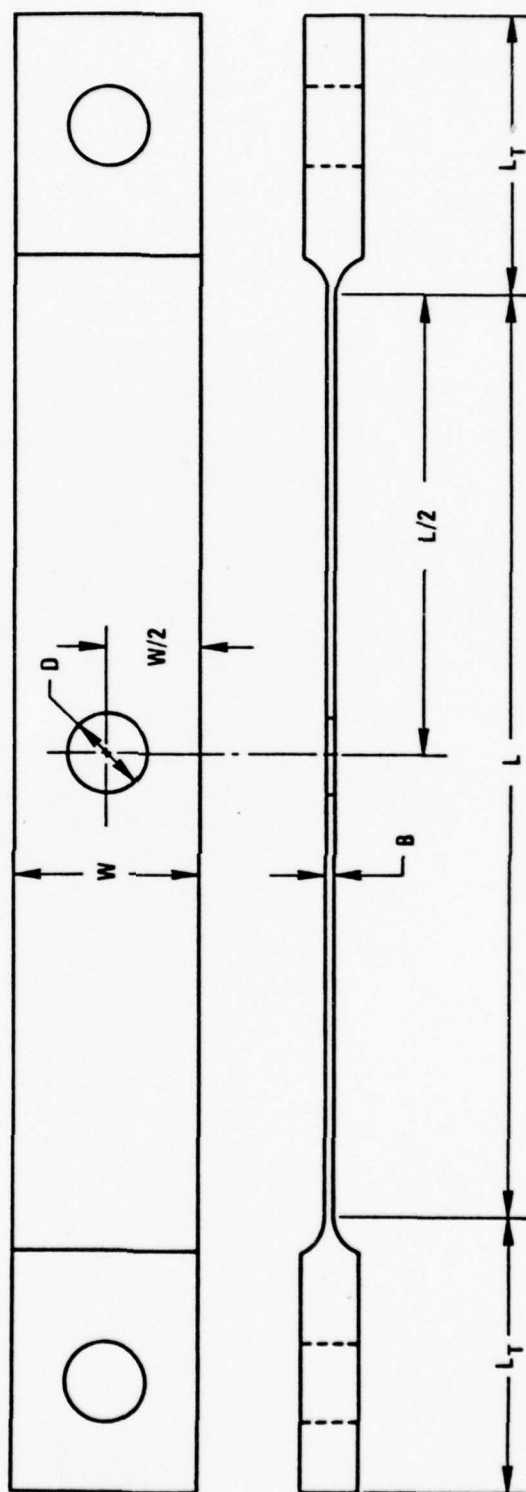


Figure 2. Schematic Configuration of Type 1b Specimen

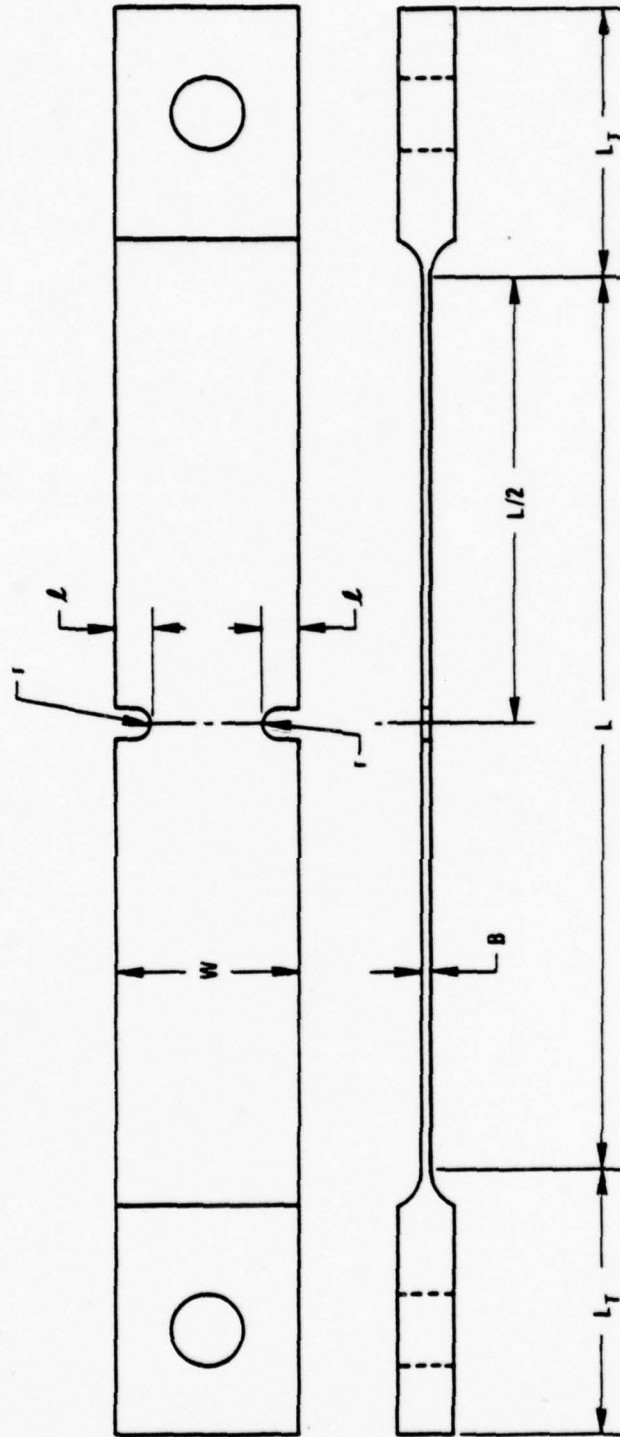


Figure 3. Schematic Configuration of Type Ic Specimen

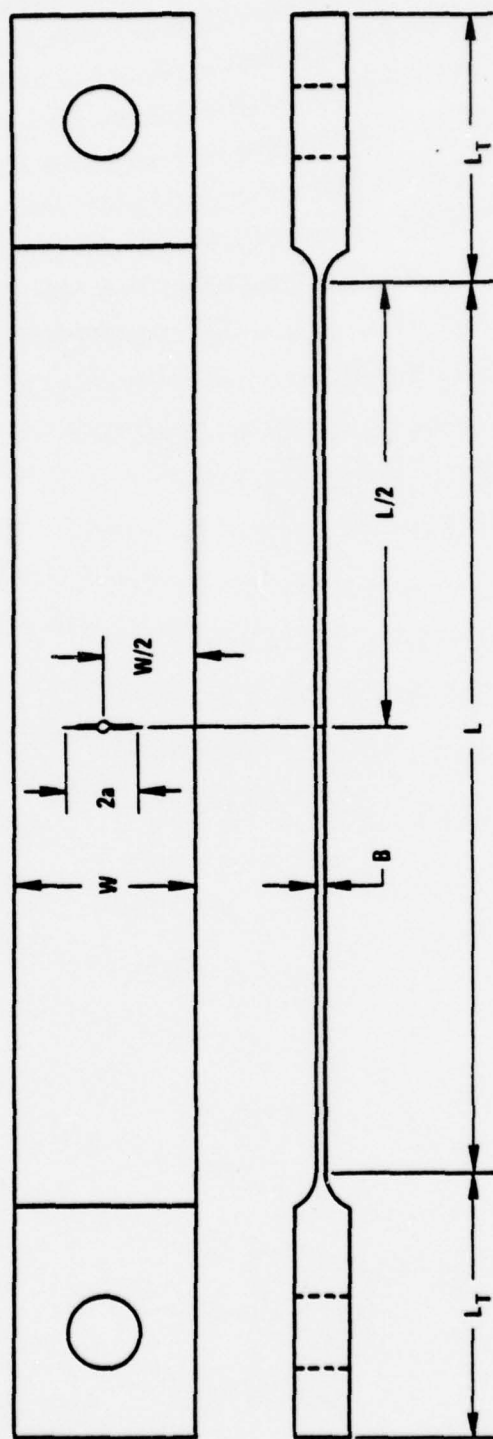


Figure 4. Schematic Configuration of Type Id Specimen

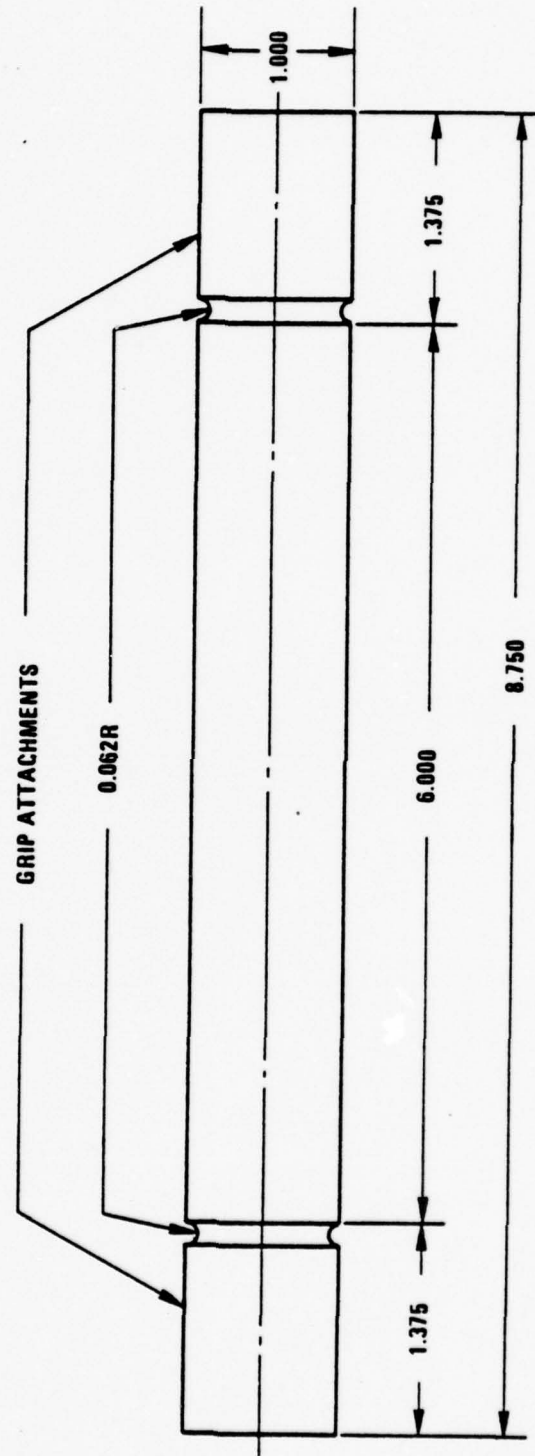


Figure 5. Schematic Configuration of Type 2a Specimen

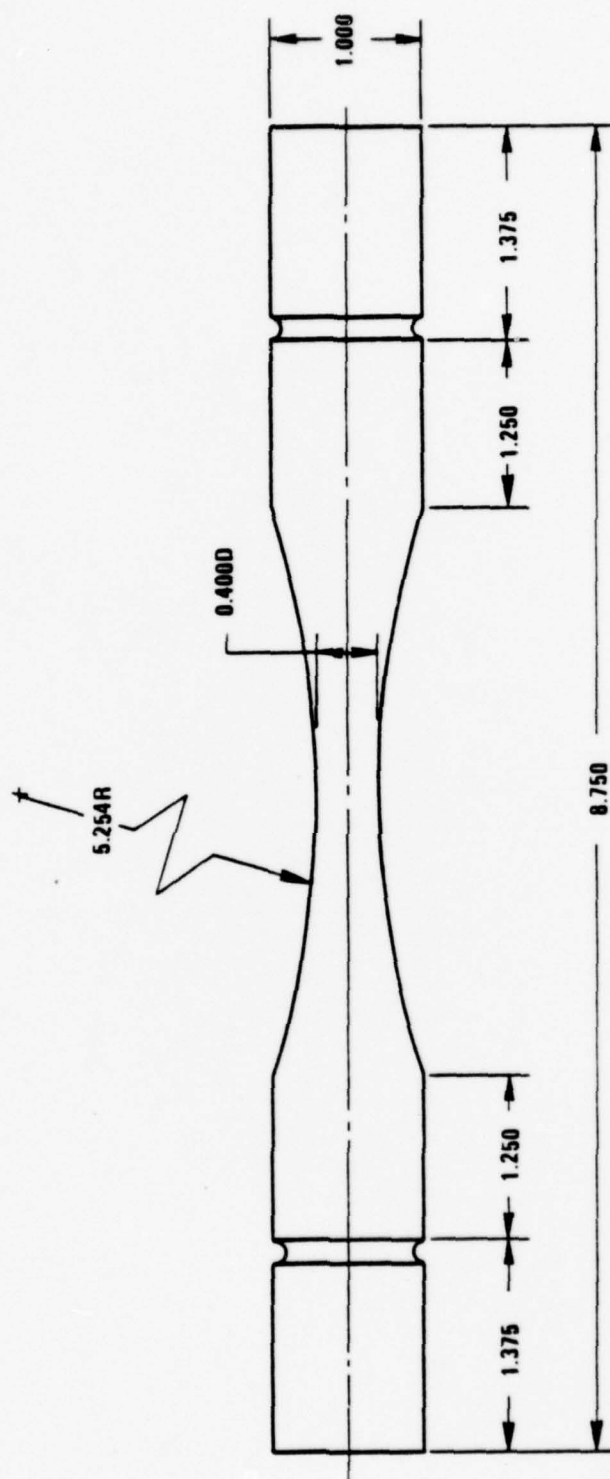


Figure 6. Schematic Configuration of Type 2b Specimens

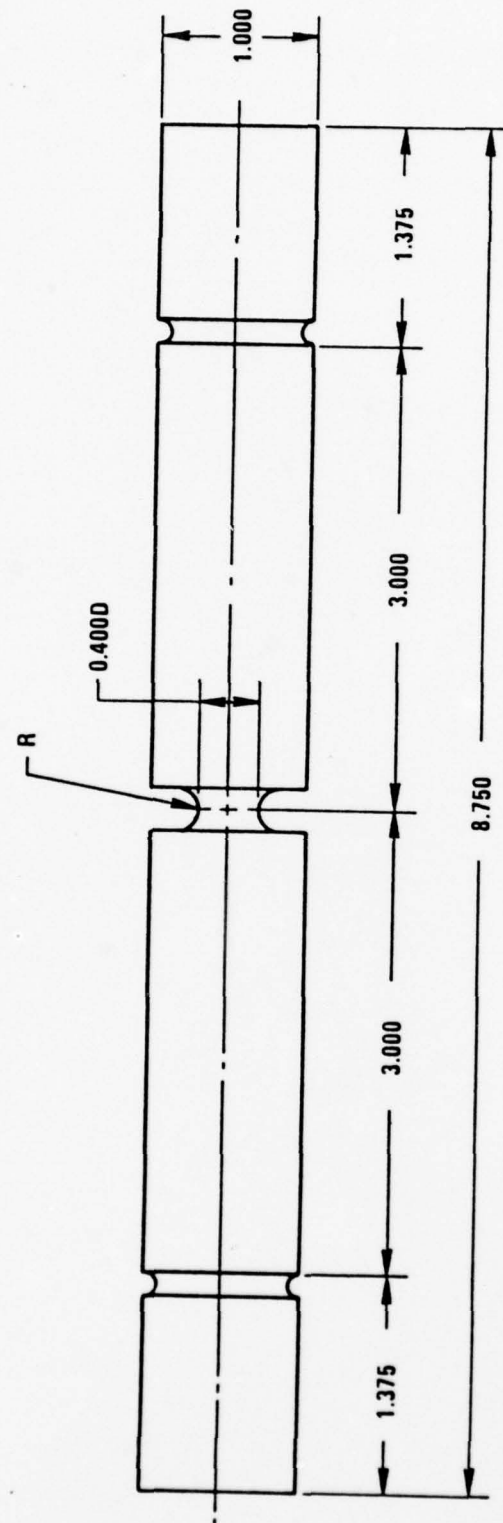


Figure 7. Schematic Configuration of Type 2c and Type 2d Specimens

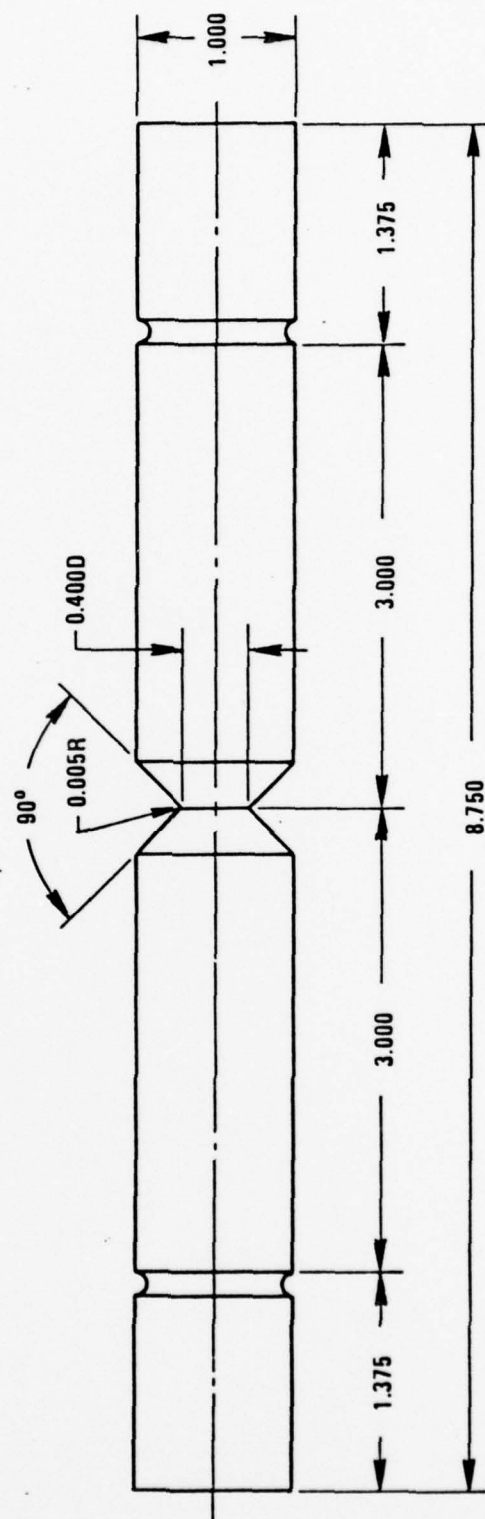


Figure 8. Schematic Configuration of Type 2e Specimen

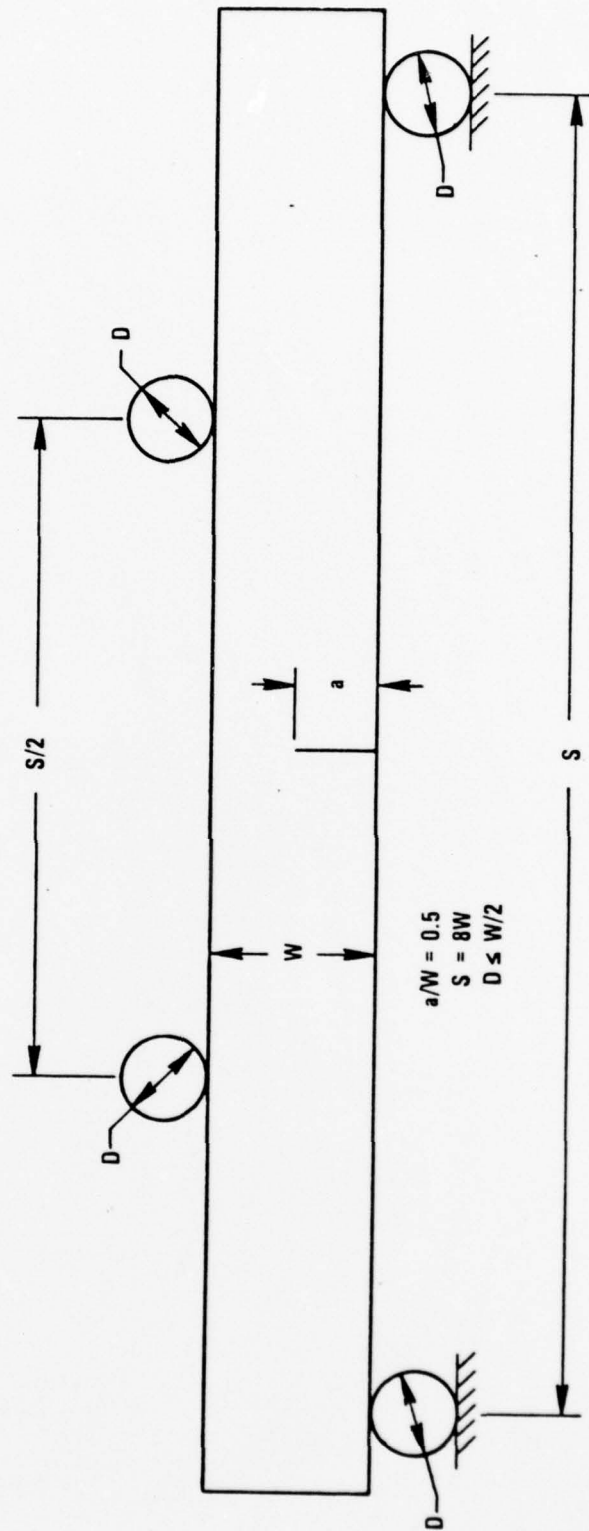


Figure 9. Schematic Configuration of Type 3a Specimen

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20. in fracture testing. The sequence of problems is intended to identify the essential needs for modeling of such problems to produce accurate results. The plan is described in terms of procedure and phasing over a two-year period, and the problems are described in terms of their experimental set-up. Thin-plate, round, and thick-section configurations are included. The report was prepared by a Planning Committee of experts in the field, and a preliminary draft was reviewed by a larger Advisory Group. Comments received during this review process are incorporated into this report.



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